NUMERICAL INTEGRATION STUDY OF PRIMORDIAL CLEARING OF THE ASTEROID BELT. G. W. Wetherill & J. E. Chambers*, DTM, Carnegie Institution of Washington, Washington, DC 20015-1305, USA (*Presently at the Armagh Observatory, Armagh, Northern Ireland).

The characteristic feature of the Solar System's asteroid belt is its great depletion in surface density of solid matter, and the absence of large planets in this region. Qualitatively, many hypotheses can be made to explain this observation. The present study addresses the hypothesis that the initial surface density of solid matter in this part of the Solar System was similar to that in the terrestrial planet and Jupiter regions, and that in accordance with theoretical investigations of the growth of planetesimals into $\sim 10^{26}$ - 10^{27}g planetary embryos (1,2), an assemblage of such bodies were formed in the asteroid belt.

It has been proposed that a dynamical system of this sort will be unstable in the presence of the larger planets of our Solar System. This suggestion was illustrated by use of a Monte Carlo approach in which the effects of the Jovian commensurability resonances and the Jupiter-Saturn secular resonance ν_6 were simulated by diffusion of the eccentricity of bodies within these resonances (3). It was found that the mutual perturbations of the asteroidal embryos, together with these resonances and close planetary encounters, were capable of removing all the embryos from the asteroid belt in about half the Monte Carlo simulations.

In order to give this proposal a stronger theoretical basis, an investigation is being carried out in which the orbital evolution of the system is determined by numerical integration of the motion of the asteroidal embryos as well as that of associated terrestrial and giant planets. The purpose of the study is to understand the circumstances under which asteroidal clearing occurs and when it does not. It is not intended to represent a model for the formation of the larger planetary bodies, but rather to determine the sensitivity of asteroidal clearing to different assumptions regarding such models.

The integrations were made by the use of a hybrid Bulirsch-Stoer and symplectic integration program based on the MVS and BS programs generously provided by H. Levison. Typically, about 25 embryos and 4 larger planets are integrated for $\sim$ 100 m.y.

The results of two such calculations are presented here. In the first (Fig. 1) the evolution of 26 Mars-size embryos in initial non-crossing orbits is calculated. Initial semi-major axes range from 1.23 AU to 4.87 AU and are spaced at about 10 mutual Hill radii (4). Within only 10 m.y. the orbits migrate widely in semi-major axis, and reach high eccentricities and inclinations. At this time more than half the original bodies have been lost from the system, mostly by ejection or sun-grazing. By 80 million years all of the embryos have been removed. The eccentricity of the Earth is oscillating between 0.03 and 0.12.

In the second example (Fig. 2), the initial state does not include ‘‘Earth" and ‘‘Venus," only Jupiter, Saturn and 21 asteroidal embryos. In the calculation shown in Fig. 1, Earth and Venus perturbations played an important role in the orbital evolution of the smaller embryos. However, even in the absence of these planets, clearing of the asteroid belt occurs. At the end of the calculation, three embryos remain near the position of the present Mars. These results, together with several others completed or underway, show that primordial clearing of embryos from the asteroid belt is a viable hypothesis. It remains to be seen how robust this process is, and the extent to which it is consistent with other observational constraints.

References:

(1) G. W. Wetherill and G. R. Stewart, *Icarus 106*, 190-209, 1993.

(2) S. J. Weidenschilling and D. R. Davis, LPS XXVII, 1401-1402.

(3) G. W. Wetherill, *Icarus 100*, 307-325, 1992.

(4) J. E. Chambers, G. W. Wetherill, and A. P. Boss, *Icarus 119*, 261-268, 1996.

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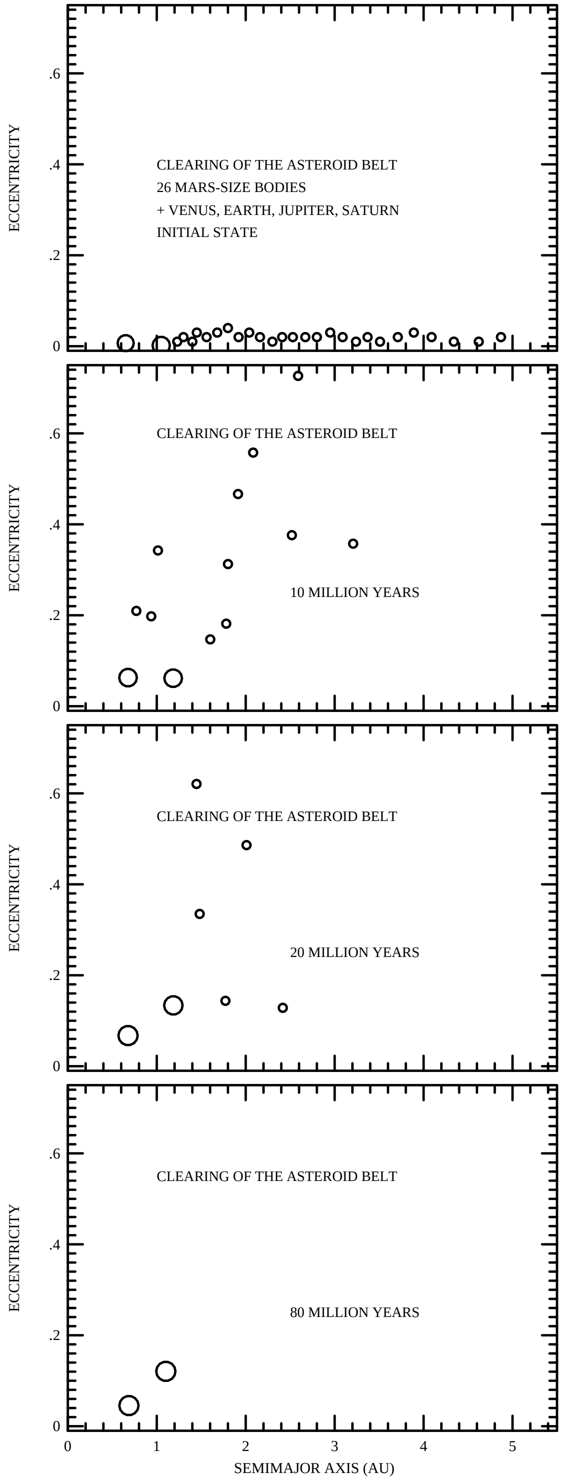

Fig. 1. Evolution of Mars-size bodies in an asteroid belt bordered by bodies the size of Earth, Venus, Jupiter, and Saturn

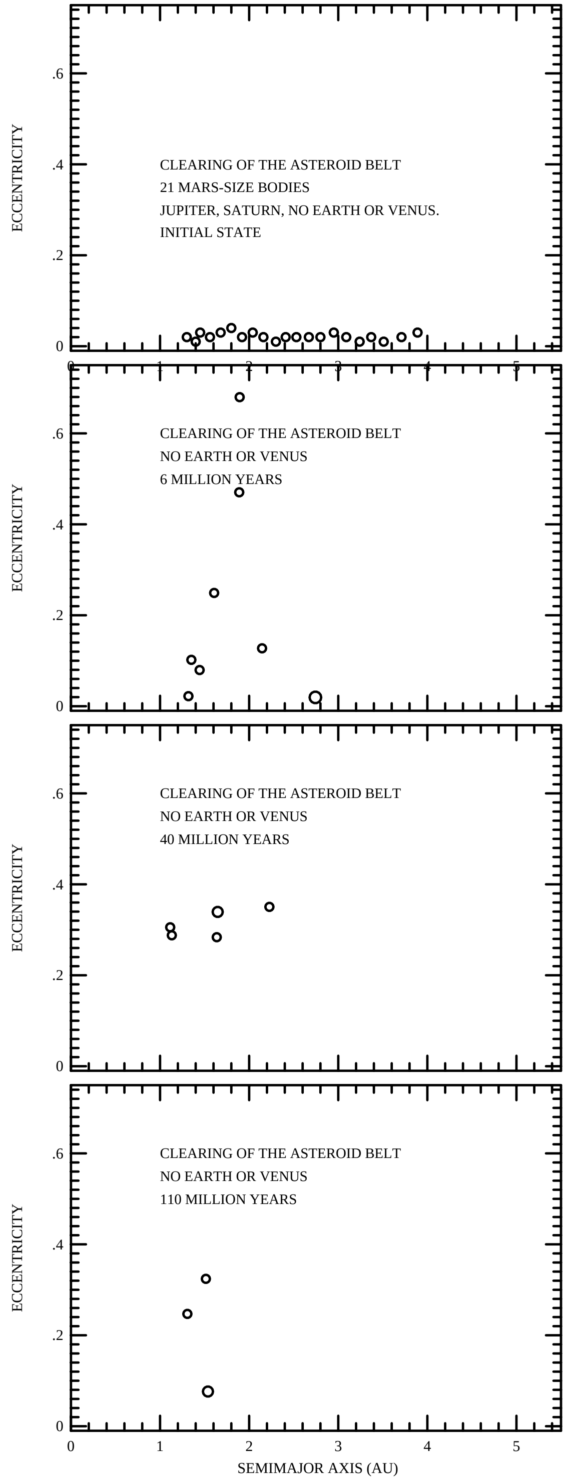

Fig. 2. Similar to Fig. 1, except that "Earth" and "Venus" are absent.